FEATURE

PHOTO CREDIT: CARLOS DELGADO

Digging Deep

Propelling St. Patrick's Cathedral Forward

BY MARY KATE MCGOWAN, ASSOCIATE EDITOR, NEWS

Before a renovation that began 11 years ago, St. Patrick's Cathedral in New York was running on city steam, and its mechanical systems were in need of an upgrade.

Following a $177 million renovation that touched all of the 139-year-old cathedral as far as the top of its spires, a geoexchange (geothermal) heat pump system now heats and cools the cathedral.

The system has a projected energy cost savings of $2 million over 20 years and an annual reduction of CO_2 emissions of about 94,000 kg (103.6 tons), said John Rhyner, vice president Geothermal Services at P.W. Grosser Consulting, Inc. in Bohemia, N.Y.

For the mechanical renovations, St. Patrick's looked into three plant options: a conventional system, a geothermal system or buying CHW and HW from nearby Rockefeller Center.

"Geothermal was chosen because it had the lowest first cost and long-term operations and maintenance compared to the other options," said Rhyner.

After a thoroughly conducted comparative analysis of three types of systems projecting out 20 years, the geothermal system was selected by the client because it provided the most benefits on multiple fronts, according to Jeffrey Murphy, partner at Murphy Burnham & Buttrick Architects in New York City.

"Making a system that minimizes altering the architecture of this iconic, historically significant building was paramount. The way in which heating and cooling distribution was carefully integrated into existing housings and infrastructure ensures that worship and the experience of the 5 million yearly visitors is not impacted by the new mechanical system," said Murphy.

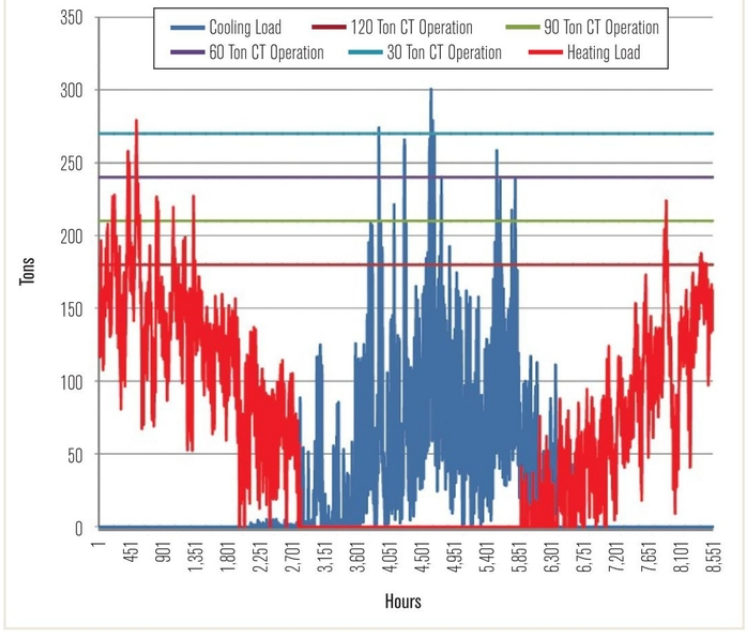
Designing for Efficiency, Geothermal

Rich Sileo, P.E., Associate Member ASHRAE, said his team knew they could not take the conventional approach to mechanical systems and install equipment on the roof or in plain view of this prominent and historic structure.

Designing a system that will work for more than 20 years, Sileo said his team selected the most energy efficient and sustainable pieces of equipment that could be easily changed out.

The geothermal system is able to provide full heating and cooling capacity for the entire campus with basically zero impact to the historic structure of the building, said Sileo, a senior engineer at Landmark Facilities Group in Norwalk, Conn.

FIGURE 1 St. Patrick Cathedral's load profile.



The system's standing column wells and compact mechanical plant are all below grade and invisible to the public, he said.

St. Patrick's uses no fossil fuels on its campus, and its carbon footprint is remarkably low, Sileo said. The only carbon emissions come from those generated by the electric utility provider.

The geothermal piping network spans a whole city block and includes service to all three buildings: the cathedral, a four-story parish house/rectory and the cardinal's residence, said Sileo.

The St. Patrick's renovation was different on several levels than a commercial building project. St. Patrick's Cathedral opened in 1879 and has no plans of closing.

"St. Patrick's Cathedral is going to be here as a treasured place of worship in 500 years, so our client has a very different performance horizon than a typical commercial building owner. For important institutions that are here to stay, there are more compelling reasons to consider geothermal technology," said Murphy.

How Deep Does It Go?

The geothermal system includes 10 wells, with each providing about 25 tons (87.9 kW) of heating and cooling capacity on average, said Rhyner. The wells were drilled through the outdoor terraces located on the north and south sides of the cathedral. They are spaced about 50 ft (15.2 m) apart.

Breaking Down St. Patrick's Cathedral's Geothermal System

Number of Wells 10, each has a heating and cooling capacity of about 25 tons (87.9 kW)

Depth Range from 800 ft (243.8 m) to 2,200 ft (670.5 m) deep, average 1,650 ft (502.9 m)

Features 10 standing column wells; 10 plate and frame heat exchangers; evaporative fluid cooler with capacity of 120 tons; natural gas-fired boilers with capacity of 2 MBtu/h (586.1 W); heat recovery chiller/heater with a capacity of 240 tons (844 kW); four pipe water distribution; primary-secondary pumping arrangements; digital control system

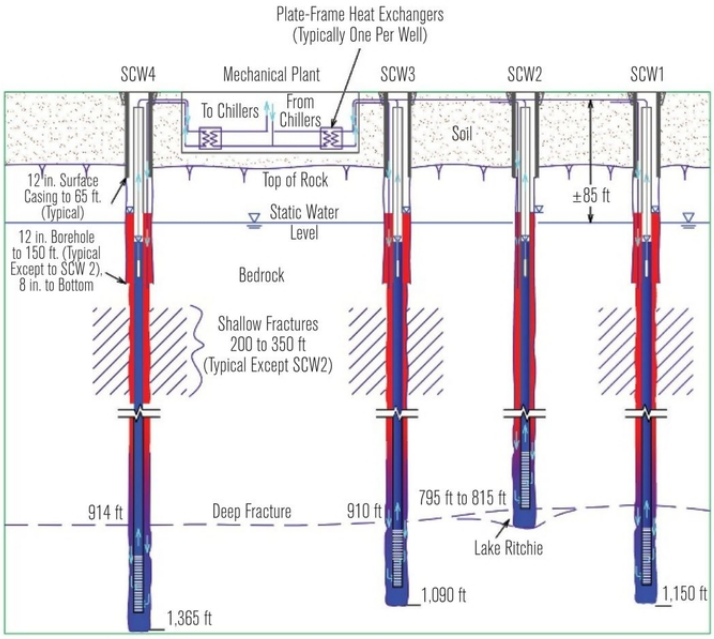
Benefits Eliminates the cathedral's reliance on steam heat; reflects Pope Francis' vision of preservation and responsible stewardship of the planet; no noise pollution, on-site greenhouse gas or particulate emissions; no steam or hot air plumes; No impact on the cathedral's visual aesthetics

The deepest well is 2,220 ft (670.5 m) deep under St. Patrick's—more than 6.5 times as deep as the cathedral's 339-foot (103.3 m) spires. The shallowest well reaches 800 ft (243.8 m), with the average well depth at about 1,650 ft (502.9 m) deep, said Rhyner.

The wells were drilled using air rotary drilling with a percussion hammer set above the drill bit at the bottom. There is a very thin layer of unconsolidated soil at the surface followed by solid bedrock, said Rhyner.

The rock does have some water-bearing fractures and groundwater fills up the hole to a certain depth depending on site conditions. In this case, the "static" groundwater level beneath the cathedral was found at about 80 feet (24.4 m) below grade, said Rhyner. Each well has a straw-like shroud inserted to the bottom and a submersible pump was set into the water column inside the shroud to a depth of about 150 feet (45.7 m) below grade, he said.

FIGURE 2 As-built conditions for St. Patrick's Cathedral's geothermal system's north-site wells.



Note: Illustrates the cooling mode groundwater circulation between the wells and heat exchangers in the mechanical plant.

Water is pumped up through the shroud and runs through a plate-frame heat exchanger in the mechanical plant, located underground in the Parish House, he said. The heat is exchanged there between the well loop and the building loop and the water is then returned into the well, as shown in *Figure 2*. The bedrock and groundwater beneath the cathedral have an average ambient, or natural, temperature of about 60°F (15.6°C). The temperature of the circulating groundwater, however, varies seasonally during operation, ranging from a low of about 50°F (10°C) in the winter to a high of about 85°F (29.4°C) in the summer, according to Rhyner.

A full building management system (BMS) starts the pumps when heating or cooling is needed at the campus above. Each well works independently.

The heart of the system is a dedicated heat recovery chiller that is modular in design, said Sileo. The chiller extracts thermal energy from the well water and distributes it throughout the campus for heating and cooling needs.

"The central plant has the capacity to generate 2.9 million Btu's per hour of air conditioning and 3.2 million Btu's per hour of heating for the 76,000 ft^2 (7060 m^2) of indoor space," according to P.W. Grosser Consulting.

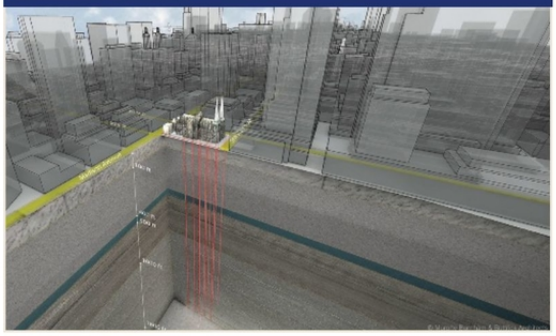
As opposed to other geothermal plants, this plant is designed to automatically split its cooling and warming functions.

The heat recovery chiller consists of eight modules that can fit through a doorway, which will help when one should need to be replaced down the road, Sileo said. The system employs a proprietary innovative technology, which allows the eight modules to be in heating or cooling mode at any time, he said.

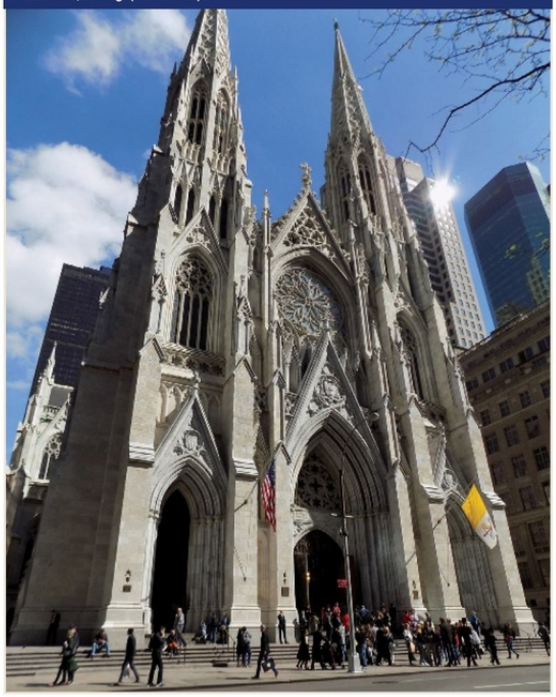
"It allows us to simultaneously deliver hot water and heat to some areas and some buildings on the campus while other buildings might at that same moment require cooling or chilled water," he said.

Well drilling began in March 2015 and lasted about nine months. The areas where the wells were drilled

FIGURE 3 St. Patrick Cathedral's geothermal system includes 10 wells with depths that range from 800 ft (243.8 m) to 2,200 ft (670.5 m) deep. Credit: Murphy Burnham & Buttrick Architects



An 11-year, $177 million renovation resulted in projected energy cost savings of $2 million over 20 years and an annual reduction of CO_2 emissions of about 94,000 kg (103.6 tons).



have since been re-graded, and the Church has planted trees and plants, Rhyner said. Ornamental well covers set flush-to-grade will provide future access when it is time to replace the well pumps, and are the only visible evidence of the drilling.

The geothermal system went on-line in the summer of 2016, concurrent with commissioning. It officially went on-line in February 2017, according to Rhyner.

Benefits of Geothermal

There are three primary benefits of the geothermal system in its application at the Cathedral: energy efficiency to support sustainability goals, high quality preservation supporting design team's architectural objectives and an enhanced user experience in support of the client's humanistic agenda, said Murphy.

The geothermal system has no carbon emissions, and it did not require any exterior modifications that detract from the cathedral's original aesthetics, he said.

A geothermal system was not initially selected to heat and cool St. Patrick's campus, Murphy said. Instead, the original plan was to install a conventional system, which would have interrupted the buildings' existing fabric, been noisy and been visible, he said.

"We have this World Class architectural gem in our hands, and our job is to be good stewards. Yet, we knew that if we put a conventional plant in the building that it would have a pretty profound impact on the campus," Murphy said. "(Geothermal) has virtually no impact on the physical fabric of the building. You simply don't see it."

The geothermal system was seamlessly integrated into the existing structure, including ornamental enclosures that were previously used to cover steam radiators for heating at the floor level, Rhyner said.

The cathedral was previously heated using district steam heat and the design team knew they could not run ductwork in the open or create new openings in walls, ceilings or floors, Sileo said. Bound to working inside the radiator enclosures, Sileo said the team chose modern fan coil units that would receive hot water from the geothermal plant.

Radiator enclosures required no modifications but do require more regular access, he said.

The cathedral's heating and cooling equipment are independent. The cooling comes from fan coils located on a Triforium level about 50 ft (15.2 m) above the sanctuary floor. Chilled water was already being delivered to that level, so it was decided to work within the existing infrastructure, he said.

Contingency

St. Patrick's geothermal system was a first for the Archdiocese of New York, and because it was a new kind of system for them, the design team and ownership elected to incorporate supplemental conventional equipment into the system design as a contingency.

The campus does have a backup cooling tower and new high efficiency boilers in case the geothermal system cannot meet demand. The boilers are designed to meet the campus' full heating demand.

Since the geothermal system went on-line, the backup heating and cooling systems have not been needed, Rhyner said. "The capacity of the wells has been more than sufficient," he said.

Surprises and Challenges

St. Patrick's Cathedral was open to the public during the renovation. Work had to stop every day at noon for daily mass, said Rhyner.

Because the church was open, containing the drilling noise was a challenge. During the drilling process, sound-absorbing blankets were attached to scaffolding constructed around the drill rig and auxiliary compressors, he said.

Another challenge happened during the drilling process. Anticipating mostly solid bedrock with just enough water-bearing fractures to fill the wells with groundwater, which is typical for New York City, the bedrock liberated abundant flow of groundwater, said Rhyner.

"It was highly unusual. We encountered a very high-yielding zone in the bedrock down about between 800 and 900 ft (243.8 and 274.3 m) and it was continuous throughout the site and at all of the wells," he said.

Groundwater in bedrock is good for thermal capacity, but the amount of water encountered mandated a few adjustments be made during the drilling process, he said.

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The groundwater quality was a concern that had to be addressed, said Sileo.

"The material of the piping and the heat exchanger, really all of the equipment the water will come in contact with, needs to be carefully chosen based on the water chemistry," Sileo said.

After testing the groundwater, the results showed that high-grade stainless steel would be the most sustainable material for the well pumps to protect against corrosion, Rhyner said.

The plate-frame heat exchangers that were installed are made of titanium, which is the most corrosive-resistant material available, according to Sileo. He said titanium should offer more years of trouble-free service.

Top Left During the drilling process, sound-absorbing blankets were attached to scaffolding constructed around the drill rig and auxiliary compressors. Top Right Existing infrastructure was repurposed throughout the project. The mechanical room was modified to house the geothermal plant. Bottom Heated and chilled water is produced by a reversible heat recovery chiller, along with the associated equipment and a new chilled and hot water piping distribution system installed throughout the campus. Photo credit: P.W. Grosser Consulting, Inc.

Those years of trouble-free service could pale in comparison with how many more years the doors of St. Patrick's Cathedral will be open to the public. ■

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